

CORRELATION OF MAP UNITS OFFSHORE GEOLOGIC AND GEOMORPHIC UNITS ONSHORE GEOLOGIC AND GEOMORPHIC UNITS >TERTIARY State Waters CRETACEOUS

LIST OF MAP UNITS

[see Description of Map units (Chapter 8, in pamphlet) for complete map unit descriptions]

OFFSHORE GEOLOGIC AND GEOMORPHIC UNITS

[Note that composite units (gray-stippled areas) are designated on map by composite label indicating both overlying sediment cover and lower (older) unit, separated by slash (for example, Qms/KJf indicates that a thin sheet of Qms

Artificial seafloor (late Holocene)—Includes dredges navigation channel and related spoils, winnowed waste disposal site, and sewage outfall pipe and related scour channel

Qms Marine nearshore and shelf deposits (late Holocene)—Predominantly sand; ripples common; winnowed by Qmsc Coarse-grained marine nearshore and Golden Gate channel deposits (late Holocene)—Coarse sand,

Marine sediment wave deposits (late Holocene)—Predominantly sand; formed by strong tidal currents at and near constricted entrance to San Francisco Bay Marine ebb-tidal channel(?) deposits (late Holocene)—Predominantly sand; found landward of San Francisco Bar at mouth of San Francisco Bay

gravel and cobbles

Marine ebb-tidal bar deposits (late Holocene)—Sandy sediment forming horseshoe-shaped bar outside the mouth of San Francisco Bay; ripples, dunes, and rills common Marine shelf scour depressions (late Holocene)—Inferred to be coarse sand and gravel filling depressions

Qbd San Francisco Bay deposits (late Holocene)—Predominantly sand Qbdc San Francisco Bay deposits, coarse-grained (late Holocene)—Predominantly coarse sand, gravel, and

cobbles; winnowed by tidal currents Merced Formation (Pleistocene and Pliocene)—Poorly indurated to friable sandstone, siltstone and claystone, with some conglomerate lenses and a few beds of volcanic ash Franciscan Complex, undivided (Cretaceous and Jurassic)—Mainly sandstone, shale, melange, greenstone,

ONSHORE GEOLOGIC AND GEOMORPHIC UNITS [Units are compiled from Bonilla (1961, 1998), Knudsen and others (1997), Brabb and others (1998), and Witter and

others (2006); unit ages, which are from these sources, reflect local stratigraphic relations] af Artificial fill (late Holocene)—Material deposited by humans

afem Artificial fill over estuarine sediment (late Holocene)—Material deposited by humans over estuarine

Artificial-levee fill (late Holocene)—Artificial levees bordering rivers, streams, salt ponds and sloughs; constructed for the purpose of containing flood or tidal waters

Artificial-dam fill (late Holocene)—Earth- or rock-fill dams, embankments, and levees; constructed to impound land-locked water bodies Alluvial fan deposits (late Holocene)—Alluvial fan deposits; latest Holocene (<1,000 years) in age, on basis of records of historical inundation or presence of youthful braid bars and distributary channels

Beach sand (late Holocene)—Active beaches in coastal environment; may form veneer over bedrock platform

Qds Dune sand (Holocene)—Active dunes and recently stabilized dunes in coastal environments

San Francisco Bay mud (Holocene)—Sediment deposited at or near sea level in San Francisco Bay estuary that is presently, or was historically, tidal marsh, mud flat, or bay bottom Alluvial fan deposits (Holocene)—Sediment deposited by streams emanating from mountain canyons onto alluvial valley floors; includes debris-flow, hyper-concentrated mudflow, and braided stream deposits

Alluvial deposits, undivided (Holocene)—Alluvium; deposited in fan, terrace, or basin environments **Colluvium (Holocene)**—Loose to firm, unsorted sand, silt, clay, gravel, rock debris, and organic material, in

Dune sand (Holocene and late Pleistocene)—Very well sorted fine to medium grained eolian sand; younger

Alluvial fan deposits, undivided (Holocene and late Pleistocene)—Mapped in small valleys where separate

fan, basin, and terrace deposits could not be delineated at map scale Landslide deposits (Holocene and Pleistocene)—Disintegrated bedrock; physically weathered; ranges from deep-seated landslides to active colluvium Older alluvial fan deposits (late Pleistocene)—Mapped where late Pleistocene age is indicated by greater

Colma Formation (Pleistocene)—Arkosic sand with subordinate gravel, silt and clay Merced Formation (Pleistocene and Pliocene)—Poorly indurated to friable sandstone, siltstone, and

claystone, with some conglomerate lenses and a few beds of volcanic ash Franciscan Complex, undivided (Cretaceous and Jurassic)—Mostly graywacke and shale. Locally divided into following subunits:

dissection or soil development than is present on Holocene fans (Qyf, Qf)

Sandstone and shale in San Bruno Mountain terrane (Cretaceous) Massive sandstone (Cretaceous)

Thin-bedded sandstone and shale (Cretaceous)

Greenstone in Permanente terrane (Cretaceous)

Graywacke in Marin Headlands terrane (Cretaceous)

Diabase in Permanente terrane (Cretaceous) Metamorphic rocks in Yolla Bolly terrane (Cretaceous and Jurassic)

Chert in Marin Headlands terrane (Cretaceous and Jurassic)

entral Belt Mélange (Cretaceous and Jurassic)—Variously-sized blocks and slabs of greenstone, serpentinite, chert and other metamorphic rocks in argillite matrix. Two units are identified separately where large enough to be shown on map: Serpentinite (Jurassic)

Metamorphic rocks (Jurassic)

Metagreenstone in Yolla Bolly terrane (Jurassic)

Greenstone in Marin Headlands terrane (Jurassic)

EXPLANATION OF MAP SYMBOLS

———— Contact—Solid where location is certain, dashed where location is approximate **Fault**—Solid where location is certain, dashed where location is approximate or inferred, dotted where location

is concealed, queried where uncertain **Folds**—Solid where location is certain, dashed where location is approximate or inferred, dotted where location is concealed

Anticline

Approximate modern shoreline—Defined as Mean High Water (MHW) (+1.46 m), North American Vertical Datum of 1988 (NAVD 1988)

3-nautical-mile limit of California's State Waters

Area of "no data"—Areas beyond 3-nautical-mile limit of California's State Waters were not mapped as part of California Seafloor Mapping Program

— 10 — Bathymetric contour (in meters)—Derived from modified 2-m-resolution bathymetry grid. Contour interval:

DISCUSSION Marine geology and geomorphology were mapped in the Offshore of San Francisco map area from approximate

Blake and others (2000), and Witter and others (2006).

Mean High Water (MHW) to the 3-nautical-mile limit of California's State Waters. MHW is defined at an elevation of 1.46 m above the North American Vertical Datum of 1988 (NAVD 88) (Weber and others, 2005). Offshore geologic units were delineated on the basis of integrated analyses of adjacent onshore geology with multibeam bathymetry and backscatter imagery (sheets 1, 2, 3), seafloor-sediment and rock samples (Reid and others, 2006), digital camera and video imagery (sheet 6), and high-resolution seismic-reflection profiles (sheet 8). Onshore geology was compiled from Bonilla (1961, 1998), Knudsen and others (1997), Brabb and others, (1998),

The Offshore of San Francisco map area includes the Golden Gate channel which connects the Pacific Ocean and San Francisco Bay. San Francisco Bay, the largest estuary on the U.S. west coast, is located at the mouth of the Sacramento and San Joaquin rivers and drains over 40 percent of the state of California. The large surface area of the bay and diurnal tidal range of 1.78 m creates an enormous tidal prism (about 2 billion m³) and strong tidal currents, commonly exceeding 2.5 m/s (Barnard and others, 2006a,b, 2007). Acceleration of these currents through the constricted channel has led to scouring of a bedrock channel that has a maximum depth of 113 m. Large fields of sand waves (Barnard and others, 2007) (unit Qmsw) have formed both west and east of this inlet as flow expands and tidal currents decelerate (see sheets 1, 2, 3, 4). Active tidally influenced map units inside San Francisco Bay also include sand-dominated deposits (unit Qbd) and more coarse-grained sand, gravel, and pebble deposits (unit Qbdc).

Sand wave fields resulting from tidal flow are also present in the nearshore along the Pacific Coast, both north and south of the Golden Gate channel. The sand wave fields appear to be variably mobilized by both ebb and flood tides, but the presence of a large (about 150 km²) ebb-tidal delta at the mouth of the bay west of the channel indicates net sediment transport has been to the west. The ebb-tidal delta west of the Golden Gate channel is mapped as two units. The inner part of the delta (unit Qmst) comprises a semicircular, inward-sloping (for example, toward the Golden Gate channel), sandy seafloor at water depths of about 12 to 24 m. This inner delta has a notably smooth surface, indicating sediment transport and deposition under different flow regimes (defined by tidal current strength and depth) than those in which the sand

Further deceleration of tidal currents beyond the inner delta has led to development of a large, shoaling (about 8 to 12 m water depth), horseshoe-shaped, delta-mouth bar (unit Qmsb). This feature (the "San Francisco Bar") surrounds the inner delta, and its central crest is cut by a dredged shipping channel that separates the nothern and southern parts of the bar, the "North Bar" and "South Bar," respectively. The San Francisco Bar is shaped by both tidal currents and waves, which regularly exceed 6 m in height on the continental shelf during major winter storms (Barnard and others, 2007). This mix of tidal and wave influence results in a variably hummocky, mottled, and rilled seafloor, and this surface texture is used as a primary criteria for mapping the unit and defining its boundaries.

Outside the San Francisco Bar to the limits of the map area, the notably flat shelf (less than 0.2°) and the nearshore are wave-dominated and characterized by sandy marine sediment (unit Qms). Local zones of wave-winnowed (?) coarser sediment (unit Qmsc) indicated by high backscatter (sheet 3) occur along the coast offshore Ocean Beach. Unit Qmsc is also mapped inside and at the mouth of the Golden Gate channel where it presumably results from winnowing by strong tidal currents. Coarser sediment also occurs as winnowed lags in scour depressions (unit Qmss), recognized on the basis of

high-resolution bathymetry (sheets 1, 2) and backscatter (sheet 3). These depressions are typically a few tens of centimeters deep and are bounded by mobile sand sheets (for example, Cacchione and others, 1984). This unit occurs primarily in the nearshore south of the Golden Gate channel offshore of Ocean Beach (water depth less than 13 m) and north of the inlet offshore Muir Beach (water depth less than 17 m). Artificial seafloor (unit af) has several distinct map occurrences: (1) sites of active sand mining inside San Francisco Bay; (2) the dredged shipping channel at the central crest of the San Francisco Bar; (3) the sewage outfall pipe, associated

rip rap, and surrounding scour channel offshore Ocean Beach; and (4) the location of a former waste disposal site about 2.5 km offshore Point Lobos. Although the map shows the areas in which several active sedimentary units (Qmsw, Qmst, Qmsb, Qmsc, Qmss, Qbsm, Qbdc) presently occur, it is important to note that map units and contacts are dynamic and ephemeral, likely to change during large storms, and on seasonal to decadal scales based on changing external forces such as weather,

climate, sea level, and sediment supply. Dallas and Barnard (2011) have noted, for example, that the ebb-tidal delta has

dramatically shrunk since 1873 when the first bathymetric survey of the area was undertaken. They document an approxi-

mate 1 km landward migration of the crest of the San Francisco Bar, which they attribute to a reduction in the tidal prism of San Francisco Bay and a decrease in coastal sediment. The map area straddles the right-lateral transform boundary between the North American and Pacific plates and is cut by several active faults that cumulatively form a distributed shear zone, including the San Andreas Fault, the eastern strand of the San Gregorio Fault, the Golden Gate Fault, and the Potato Patch Fault (see sheets 8, 9; Bruns and others, 2002; Ryan and others, 2008). These faults are covered by Holocene sediments (mostly units Qms, Qmsb, Qmst) with no seafloor expression, and are mapped using seismic-reflection data (see sheet 8). The San Andreas Fault is the primary plate-boundary structure and extends northwest across the map area; it intersects the shoreline 10 km north of the map area at Bolinas Lagoon, and 3 km south of the map area at Mussel Rock. This section of the San Andreas Fault has an estimated slip rate of 17 to 24 mm/yr (U.S. Geological Survey, 2010), and the devastating great 1906 California earthquake (M7.8) is

thought to have nucleated on the San Andreas a few kilometers offshore of San Francisco within the map area (see sheet 9; Bolt, 1968; Lomax, 2005). The San Andreas Fault forms the boundary between two distinct basement terranes, Upper Jurassic to Lower Cretaceous rocks of the Franciscan Complex to the east, and Late Cretaceous granitic and older metamorphic rocks of the Salinian block to the west. Franciscan Complex rocks (unit KJf, undivided) form seafloor outcrops at and north of Point Lobos adjacent to onland exposures. The Franciscan is divided into 13 different units for the onshore portion of this geologic map based on different lithologies and ages, but the unit cannot be similarly divided in the offshore because of a lack of direct observation and (or) sampling. In the southern part of the map area, the San Andreas Fault also forms the

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southwestern boundary of the offshore occurrence of the Pliocene and Pleistocene Merced Formation (unit QTm).

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